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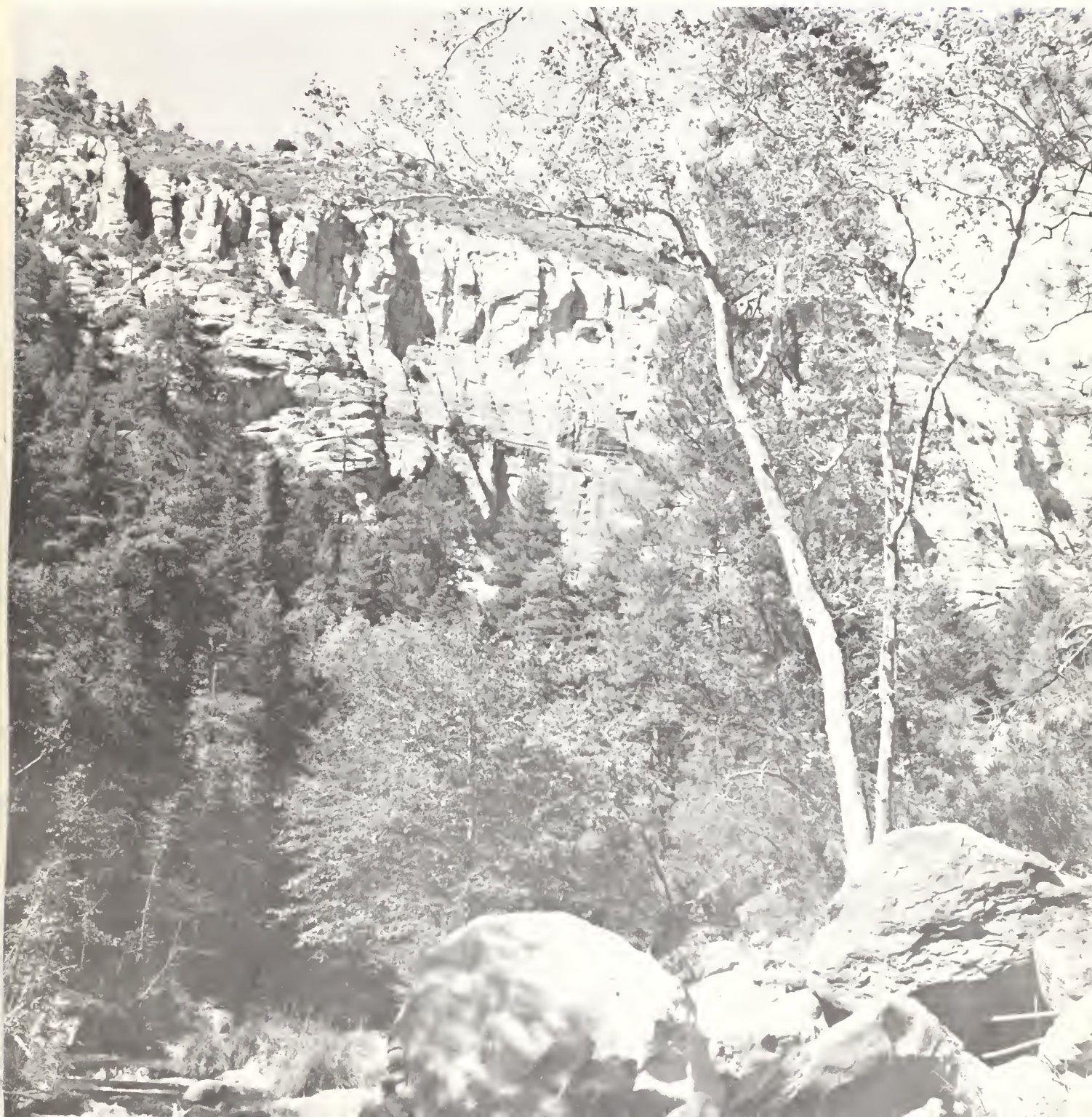
The Impact of Vacation Homes on National Forest Water Resources

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Eisenhower Consortium For Western Environmental Forestry Research

SEP 23 1977



ABSTRACT

Segall, Burton A.

1976. The impact of vacation homes on National Forest water resources. Eisenhower Consortium Bulletin 3, 19 p. Fort Collins, Colo. 80521

The research report presents the results of wastewater disposal studies in northern Arizona. The studies were undertaken to determine the impact of second homes and related vacation development on streams in semiarid regions.

The investigation showed that sewage flow rates are dependent upon home occupancy and fluctuate widely in comparison with suburban and urban areas. This sporadic waste discharge is deleterious to package plant type treatment systems. Dispersed, well designed and maintained soil disposal systems are preferred in a forest environment. Conventional sewerage systems and treatment plants concentrate wastewater flows, partially treat waste materials, and are less desirable.

The Impact of Vacation Homes on National Forest Water Resources

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This research was supported by the Forest Service, U.S. Department of Agriculture, through the Eisenhower Consortium for Western Environmental Forestry Research.

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The Impact of Vacation Homes on National Forest Water Resources

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INTRODUCTION

The number of private homes and recreational developments is increasing rapidly on the borders of National Forests. Waste materials from separate vacation homes or recreational communities can degrade forest areas and constitute a health hazard to home owners and individuals utilizing the National Forest for recreational activities. Wastewaters entering streams and lakes without prior treatment or with conventional secondary sewage treatment diminish water quality and restrict the use of water resources and contiguous forest areas.

In the semi-arid climate of Arizona, the problem is twofold. If wastewater is not sufficiently treated, diluted or disposed of in an innocuous manner, it is esthetically objectionable. But, wastewater and its nutrient constituents are valuable potential resources in a semi-arid area that can be used for plant growth both within developed areas and in surrounding forests.

A series of studies were undertaken to determine the effects of second homes and related vacation development on the quality of streams and groundwater in the National Forests of Arizona. The initial study was undertaken at a vacation home subdivision under construction in Northern Arizona--Pinewood. The community borders the Coconino National Forest and is a heterogenous development of cabins, large homes, trailers and service businesses.

Pinewood was selected for study because its composition and rate of growth appeared

to be representative of development that is occurring and probably will continue to occur adjacent to National Forest areas in Arizona. The community is served by a sewerage system that conveys wastes from homes to a secondary sewage treatment plant. Collection and transmission of sewage to a point location enables assessment of flow quantities and chemical and biological waste water characteristics. Concentration of home sewage flows is in itself a most significant potential environmental hazard.

A water reuse practice found frequently in the Southwest is utilized at Pinewood. Secondary effluent from the community's sewage treatment plant is used to water a golf course. The water, as well as the organic and nutrient materials present in the waste, are utilized for plant growth. There is a possibility that diluted wastewaters are recycled at Pinewood since the water supply for the area consists of wells which pump aquifers that underlie the golf course.

A second study was conducted in Oak Creek Canyon, an area north of Sedona, Arizona, that is within the Coconino National Forest. The Canyon is a major recreational area in northern Arizona and numerous private homes, trailer parks and Forest Service campground and picnic areas are found along the banks of Oak Creek.

Septic tanks and soil absorption systems are used exclusively in second home and trailer developments for sewage disposal. In public campground areas, the Forest Service maintains vault privies that are periodically pumped and the wastes transported by truck to landfill sites.

COLLECTING WASTEWATERS FOR POINT DISCHARGE

Study Area

The Pinewood subdivision at Munds Park, Coconino County, Arizona, is located 18 miles south of Flagstaff, Arizona, along the Black Canyon Highway. The community occupies 1,100 acres: 900 acres are allocated for home development and the remaining area is utilized for recreational purposes--primarily a golf course. The totally developed community shown in Figure 1 will consist of 3250 homes on lot sizes averaging 70 feet x 100 feet. In 1975, more than 80 percent of the total acreage available for home development had been sold but only 550 lots, or 17 percent of the area was occupied. Much of the land had been purchased for speculation.

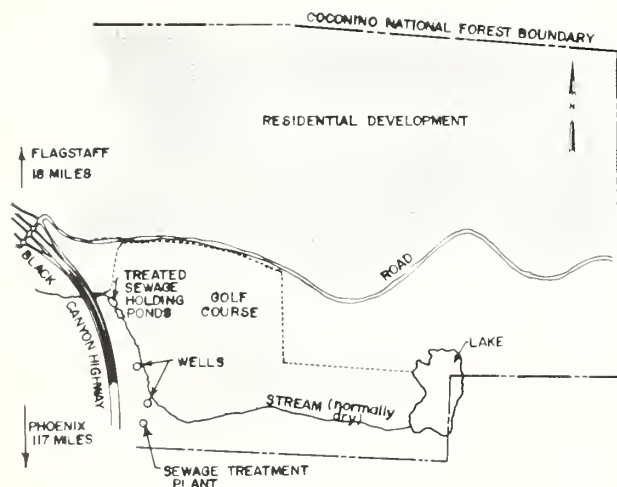


Figure 1.--Pinewood, Arizona.

Population and Type of Home Development

In August, 1972, there were 320 homes and 220 mobile homes at Pinewood, with an average occupancy of 2.5 persons per dwelling or a total of 1350 people. The population is expected to increase to about 8,000 within the next decade or about 9 persons per acre at full development. The average occupancy of suburban residences in Arizona is about 3.2 persons per household. The 2.5 persons per household estimate reflects the transitory characteristic of resort communities, i.e., less than the entire family is assumed to be in residence during a vacation weekend or an extended vacation period.

The type and size of dwelling appears to have little influence upon wastewater quantities or characteristics at Pinewood. Mobile

homes have as many bathrooms, kitchen and laundry facilities as the cabins and larger homes. The average trailer or home at Pinewood has one and one half bathrooms and about half of the homes have washing machines. With the exception of lawn sprinkler systems, the homes are as equipped with as many water-using facilities as an average home in a suburban development.

Recreational Home Use and Water Supply

Monthly water consumption data were used to estimate seasonal recreational home use and seasonal sewage flows. The Arizona Water Company operates two wells at Pinewood and occasionally, during high demand periods, a third well owned by the Pinewood Development Company. The two principal wells are 200 feet deep and are located adjacent to the Pinewood golf course. Observed water depth in one of these wells on August 5, 1972 was 173 feet. Monthly water sales and the number of customers served between September 1971 and November 1972 are shown in Table 1. The period of maximum water consumption occurs during the summer, July through August, when a majority of home owners are in residence. High demands during winter months are usually indicative of water loss due to main breaks.

A small percentage of the water supplied to consumers at Pinewood is used for consumptive purposes, i.e., lawn watering, street washing, etc. Thus, the water consumption values shown in Table 1, adjusted for the few homes and businesses that have septic tanks, are representative of sewage flows. Water consumption data indicated that about 10 percent of the population are year-round residents at Pinewood and more than half of the homeowners stay six months each year, although most of these people spend only weekends in Pinewood. The average total residence time is about 90 days per year.

Water consumption during the winter months averages 6 gallons per capita per day, based upon the total community population or about 60 gallons per capita per day for the people in residence, i.e., about 10 percent of the Pinewood population are in residence during the winter months. During the peak flow month of August, per capita consumption averaged 44 gallons per day based upon the total population.

Sewage Quantities

Sewage flows for the months of July, August, and September, 1972, were obtained from continuous flow records maintained by the Pinewood Development Company. These records

Table 1.--Water consumption at Pinewood, Arizona

Month		Number of Customers Billed	Total Water Consumption <i>gallons</i>	Household Water Use <i>gallons/month</i>	Average Per Capita Water Use <i>gallons/day</i>
1971	Sept.	485	1,363,200	2,810	37
	Oct.	496	1,122,100	2,260	29
	Nov.	504	970,800	1,930	25
	Dec.	504	238,600	470	6
1972	Jan.	516	1,100,800	2,130	28
	Feb.	512	230,300	450	6
	March	508	243,200	480	6
	April	518	212,000	410	5
	May	518	484,500	940	12
	June	555	1,108,800	2,000	27
	July	582	1,833,600	3,150	41
	Aug.	625	2,128,500	3,410	44
	Sept.	655	1,859,500	2,840	37
	Oct.	668	1,634,100	2,450	32
	Nov.	675	1,226,400	1,820	24

were not available for the entire year, but were sufficient to determine hourly and daily flow quantities during the summer months. This is the period of maximum flow and the time of year when the surrounding environment is least tolerant to the discharge of excessive quantities of liquid wastes.

Total influent flow, in August and September, 1972, to the Pinewood sewage treatment plant was 2,690,000 gallons. This estimate is 60 percent of the total water sold during that period. Average flow for the period was 42,000 gallons per day, 66 gallons per household or 26 gallons per capita per day.

Weekly and diurnal flow variations are shown in Figure 2. Maximum flow occurred on Sundays--values were about 30 percent above

weekly averages. Diurnal fluctuations, shown in Figure 2, vary from 62 percent of the mean, at 6 a.m., to 129 percent of the mean, at noon. Flow deviations from daily means were the same on weekdays and weekends.

Sewage flow estimates are summarized in Table 2. Average flow throughout the year and during the winter months, as well as maximum day and peak hour estimates, are expressed as a percentage of the maximum monthly value. The wide fluctuation in sewage flow emanating from this community is due singularly to the variability in the resident population.

During the maximum flow month of August, per capita flow was 26 gallons per day. This value is about half of the flow normally discharged by residential communities (1,2). This

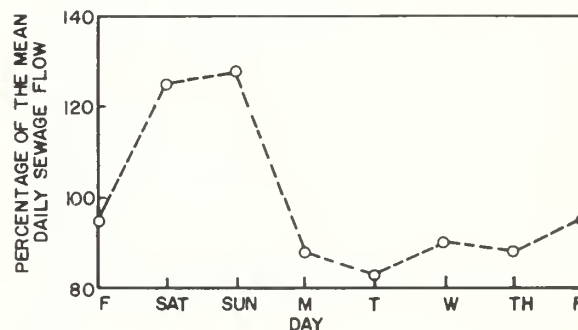
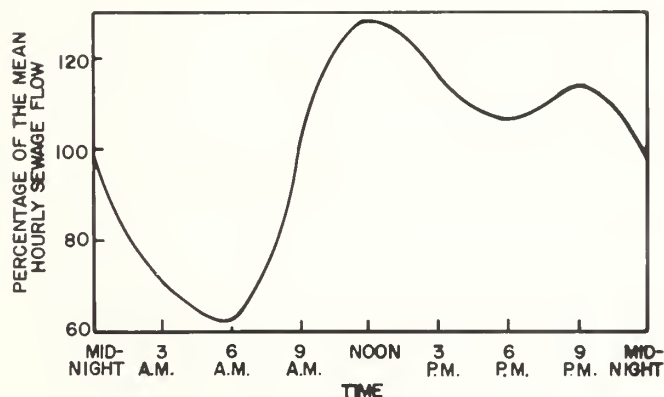


Figure 2.--Variation in sewage flow during August and September, 1972.

Table 2.--Summary of sewage flows

	Gallons per capita per day	Gallons per household per day	Percent of maximum monthly values <i>percent</i>
Average daily flow (12-month basis)	7	18	27
Average daily flow (December through April)	4	9	14
Maximum monthly flow (August)	26	66	100
Maximum day flow	33	83	126
Peak hour flow	43	107	162
	August 1972	September 1972	
Total flow, gallons	1,261,000	1,432,200	
Average day, gal/day	40,700	47,700	

result indicates that during the month, average occupancy was about 50 percent. Our observations at Pinewood also indicated that about half of the homes were in use during the month of August.

Chemical and Bacterial Characteristics of Wastewaters

Chemical and bacterial characteristics of raw sewage were determined by sampling influent flow to the Pinewood treatment plant. Treatment plant influent and effluent samples were collected between mid-July and the first week in September, 1972, and analyzed for organic materials, nutrients, and bacteria. Samples were collected on weekends, during peak flow periods.

Sewage treatment plant effluent is held briefly in a series of ponds, and subsequently used to irrigate the Pinewood golf course. Water supply wells for Pinewood are located near the treated sewage holding ponds, on the periphery of the golf course. Water from these wells and surface water were analyzed to determine whether local streams or groundwater is being contaminated by the wastewater.

The results of water and wastewater analyses conducted for this study and well water analyses conducted by the State of Arizona Health Department are shown in Tables 3 and 4. The tables show that groundwater in the area is moderately hard, but that it, in all respects, conforms with the Public Health Service Drinking Water Standards. Nitrate, phosphate, alkalinity and chloride concentrations give no indication of groundwater contamination.

The bioassay procedure for Coliform group organisms is an excellent indicator of groundwater contamination. The Arizona Water Company sends four water samples collected each month from its distribution system to the State Health Department. Since the supply is chlorinated prior to distribution, bacterial tests of these samples cannot be used to assess groundwater contamination. Samples taken directly from the wells, prior to chlorination, yielded the results shown in Table 3. All of the bacterial test results were negative, indicating the absence of sewage contamination.

Table 3 also shows both the average chemical and bacterial characteristics of wastewater discharged from this second home development, and the results of secondary waste treatment. Treated wastewater samples were taken prior to sewage chlorination. Coliform organism concentration was significantly reduced by chlorine before pumping the wastewater to irrigation ditches.

Raw sewage Biochemical Oxygen Demand (BOD) averaged 196 mg/liter, and treated effluent samples averaged 5 mg/liter, when the plant was operating properly. During two of the sampling periods, BOD exceeded 35 mg/liter, indicating plant malfunction.

Table 5 summarizes the results of the chemical analyses and shows the difference between constituent concentrations in water and sewage. Increase in constituent concentration resulting from domestic water use at Pinewood are compared in Table 5 with typical values for residential communities (3,4). This comparison shows that BOD, nitrogen, phosphorus, alkalinity and chloride concentra-

Table 3.--Results of chemical and bacterial tests

	Ground water	Sewage	Treated wastewater
Coliform group organisms MPN per 100 ml	<2	1.6×10^9	2.2×10^6
Kjeldahl nitrogen (Organic and Ammonia nitrogen) mg/l as N	0	33.6	10.8
Nitrates, mg/l as N	.9	0	10.1
Phosphorus, mg/l as P	1.8	10+	10+
Alkalinity, mg/l as CaCO_3	90	249	141
Chlorides, mg/l as Cl	4	34	37
pH	8.6	7.7	7.7
Biochemical oxygen demand (mg/l 5-day)	0	196	5 to >35

Table 4.--Analyses of well water (State Health Department)

Characteristic	Water sampled on June 29, 1971		Water sampled on April 27, 1972	
	Well #2	Well #3	Well #2	Well #3
Specific conductance, micromhos/cm	5000	5000	-	-
Total dissolved solids, mg/l	134	134	140	134
Hardness, mg/l as CaCO_3	100	100	118	114
Calcium, mg/l as Ca	26	25	28	27
Magnesium, mg/l as Mg	8	9	12	11
Sodium, mg/l as Na	5	4	5	4
Alkalinity, mg/l as CaCO_3	96	96	108	102
Chloride, mg/l as Cl	2	2	4	3
Flouride, mg/l as F	.12	.10	.09	.12
Nitrate, mg/l as NO_3	5	4	1	2
Sulfates, mg/l as SO_4	6	6	<6	<6
Chromium, mg/l as Cr	.01	.01	<.01	<.01
Iron, mg/l as Fe	.05	.05	<.05	<.05
pH	8.1	8.0	8.2	8.2
Manganese, mg/l as Mn	-	-	<.05	<.05
Copper, mg/l as Cu	-	-	<.05	<.05
Zinc, mg/l as Zn	-	-	<.05	<.2
Arsenic, mg/l as As	-	-	<.01	<.01
Silver, mg/l as Ag	-	-	<.01	<.01
Cadmium, mg/l as Cd	-	-	<.01	<.01
Lead, mg/l as Pb	-	-	<.05	<.05
Selenium, mg/l as Se	-	-	<.01	<.01
Mercury, mg/l as Hg	-	-	<.0005	<.0005
Color	-	-	<5	<5
Threshold odor number	-	-	<3	<3
Turbidity, j.u.	-	-	<5	<5

Table 5.--Summary of increase of pollutants with domestic water use

Constituent	Concentration		Typical values for residential communities	
	Results of this study			
	mg/l	lb/capita/day	mg/l	lb/capita/day
Biochemical oxygen demand	196	.095	200	.10
Organic and ammonia nitrogen as N	34	.016	30	.0145
Nitrates as N	0	.0	0	.0
Phosphates as P	10	.005	10-17	.006-.008
Alkalinity as CaCO ₃	160	.08	100-150	.05-.08
Chlorides as Cl ⁻	30	.01	20-50	.01-.02

tion increases at Pinewood are similar to results observed in residential communities.

BOD increased from zero in the potable water supply, to approximately 200 mg/l in domestic sewage. Nitrogen, as organic nitrogen, and ammonia in sewage increased 30 mg/l above nitrate nitrogen levels found in the water supply. Phosphates increased about 10 mg/l above trace levels found in the water and chlorides increased about 30 mg/l.

The Effects of Secondary Sewage Treatment

The sewage treatment plant is a 350,000 gallon per day contact stabilization package plant designed for a 5-day BOD loading of 595 lbs. per day. The average daily flow in September, was 47,700 gallons per day and the BOD concentration was 196 mg/liter. This is equivalent to a loading of 78 lbs. per day. Thus, during the maximum flow month, the treatment plant received only 13 percent of the design flow and organic loading. Under these conditions, the treatment plant should have reduced carbonaceous waste concentrations to very low levels, and usually did so. On July 10 and 28, and August 15, plant efficiency averaged 98 percent BOD removal. On August 12 and September 3, the plant apparently malfunctioned and efficiency dropped to less than 85 percent.

Under these low loading conditions, organic nitrogen and ammonia are normally oxidized to nitrates. During the upsets on August 12 and September 3, nitrogen discharged in the plant effluent was in the form of ammonia.

In summary, the Pinewood facility normally produces an effluent that has a low BOD. Nitrogen is converted from organic and ammonia nitrogen to nitrates but is not significantly reduced. Phosphate and chloride sewage concentrations are unaltered, and bacterial concen-

trations are reduced to trace amounts by chlorination.

The sewage treatment plant at Pinewood is periodically upset, even at present low loadings. This is not unusual. Secondary sewage treatment processes frequently malfunction. A report by the California State Department of Health clearly supports this conclusion:

"Experience has shown that interruption in sewage treatment is a relatively common occurrence. In 1964, the Bureau of Sanitary Engineering conducted a study of the public health aspects of sewage collection and disposal in the Central Valley. The results indicated that 56 percent of the plants had experienced equipment outages during the preceding year. Chlorination equipment was reported out of service by 18 plants, with the outage varying from an hour to an entire year. Sedimentation units were out of service in 36 plants or 11 percent of the plants. The sedimentation outages varied from an hour to 9 months. Trickling filters were reported inoperative by 20 plants and 17 digesters were reported out of service. The outages in these critical biological units ranged from an hour to 9 months. Thirty-three percent of the plants reported the necessity of bypassing untreated sewage for periods ranging from 6 hours to an incredible 300 days!" (5)

The large municipal plants discussed in the preceding quote are normally maintained and operated on a continuing basis by trained personnel. Operation and maintenance of small package plants, such as the unit in use at Pinewood, varies in Arizona from adequate to occasionally allowing plants to operate themselves--which they do not.

Package plants do an excellent job of reducing carbonaceous materials when loadings are relatively uniform and within the capacity of the particular plant. However, uniform sewage flow to these plants is the exception rather than the rule. This is particularly true at a second home development where resident population fluctuates widely on an hourly, daily, and seasonal basis.

Subsurface Sewage Disposal

The geology in the vicinity of Pinewood is predominately montmorillonite clay, formed from volcanic cinders, ash and basalt. Tertiary basalt lies immediately below the soil structure and is exposed in many areas along the perimeter of the basin that is occupied by the golf course. The majority of home sites at Pinewood are in the perimeter area. Lots are located in a shallow alluvial clay horizon, underlaid by a basalt flow. Soil permeability is slow to very slow, and excavation costs through the basalt bedrock are high.

Homes and businesses located within the basin area at Pinewood have functioning septic-tank systems. The soil in the basin area is generally deep and lot sizes are large enough for absorption field systems.

The Arizona Department of Public Health code stipulates that all portions of a septic disposal system must be more than 50 feet from a well, 10 feet from a property line, 10 feet from building foundations and may not underlie an unreinforced driveway. Lot sizes at Pinewood, averaging 70 feet by 100 feet, do not afford sufficient area for a house and an absorption field system in a low permeability soil.

Conclusion

The waste assimilative capacity of a given semi-arid watershed is dependent upon a variety of factors, the more important considerations include:

- a. the method of wastewater disposal, i.e., through sewerage systems or separate soil disposal units
- b. the completeness and variability of wastewater treatment
- c. plot size and soil permeability
- d. the type of forest environment at points of wastewater discharge, e.g., a lake, a flowing stream, a dry stream bed, or groundwater

- e. the extent and type of wastewater reuse practiced in the developed community

In the semi-arid forest environment adjacent to Pinewood, secondary waste treatment does not adequately protect the local forest environment. Stream flow is either nonexistent or does not provide sufficient dilution. Nitrogen and phosphorus in sewage are not removed by conventional processes and can easily stimulate algal blooms in lakes. Package treatment plants are easily upset and difficult to operate under the variable flow conditions experienced at recreational communities.

A solution to the wastewater disposal problem created by second home developments lies in water reuse and when possible the use of the soil for waste assimilation. Utilization of treated sewage for golf course watering at Pinewood is a prime example of the reuse potential of wastewaters. A community soil disposal system is also an alternative solution.

The waste assimilative capacity of a watershed, in which the soil is amenable to subsurface disposal, is a function of soil permeability. When a development is constructed on a low permeability soil and the community is unable to utilize treated wastewater, the discharge of organic and nutrient materials to the surrounding forest is inevitable. The effects of these discharges are variable. Treated wastewater can stimulate plant growth and benefit a forest, or it can create esthetically unacceptable conditions and potential health hazards.

NON-POINT SOURCE POLLUTION

Assimilation of Wastes in Soil and Water

Acceptable methods of waste disposal in aquatic and soil systems involve the process of assimilation. The assimilative capacity of streams and lakes has traditionally been utilized by communities for sewage disposal. Waste assimilation has long been considered a reasonable use of water resources. At first raw sewage was discharged directly to water courses--more recently, with the widespread adoption of secondary treatment, the organic content of sewage is reduced prior to diluting wastewaters into lakes and streams. Carbonaceous materials, nutrients, and dissolved contaminants that are not removed in secondary treatment invariably reach receiving water courses.

Sewage disposal in water courses often conflicts with other water uses--including

recreational uses. Recreational use of forest lakes and streams is of primary importance in Arizona's forests, particularly within Oak Creek Canyon, where the stream is used extensively for recreational purposes by a great number of people from Flagstaff and the Phoenix metropolitan area.

The earth's soil mantle is an excellent and traditional depository and treatment medium for domestic wastewaters. Soil disposal systems offer an alternative to aquatic waste disposal and consequent water pollution. Soil assimilation consists of numerous complex processes including entrapment of particles, absorption, biological decomposition and plant growth.

The particular emphasis of this study, conducted at Oak Creek Canyon, was sewage contamination of surface water resulting from subsurface sewage disposal. Soil infiltration capacity and stream pollution were investigated at campgrounds and second home developments within the canyon.

Description of the Study Area

Oak Creek Canyon lies along U.S. Highway 89A, just north of Arizona's magnificent red rock national monument at Sedona. The canyon is traversed by one of the few, free-flowing streams in the state and is heavily used as a summer recreational area. Elevation varies from 4400 feet at Sedona to 5600 feet at the upper extremities of the canyon. Privately owned homes and public campground locations are shown on Figure 3. Sewage from homes and trailer parks is disposed of through individual septic tanks; vaulted privies are used at public campgrounds.

Soils in Oak Creek Canyon

Soils in Oak Creek Canyon are recent alluvium underlain by sandstone. They are coarse textured sand and loam with predominantly an A-C horizon sequence. Soil depth is generally greater than 5 feet throughout the canyon, but outcrop areas are found adjacent to Oak Creek and on the steep slopes of the Supai sandstone formations. The most attractive homesites in the canyon are adjacent to the creek.

Soil samples were taken from campsites and developed areas throughout the canyon and analyzed to determine their suitability for subsurface wastewater disposal. Percolation tests and sieve analyses were conducted, and the resulting data were compared with Coconino County Health Department and Forest Service information.

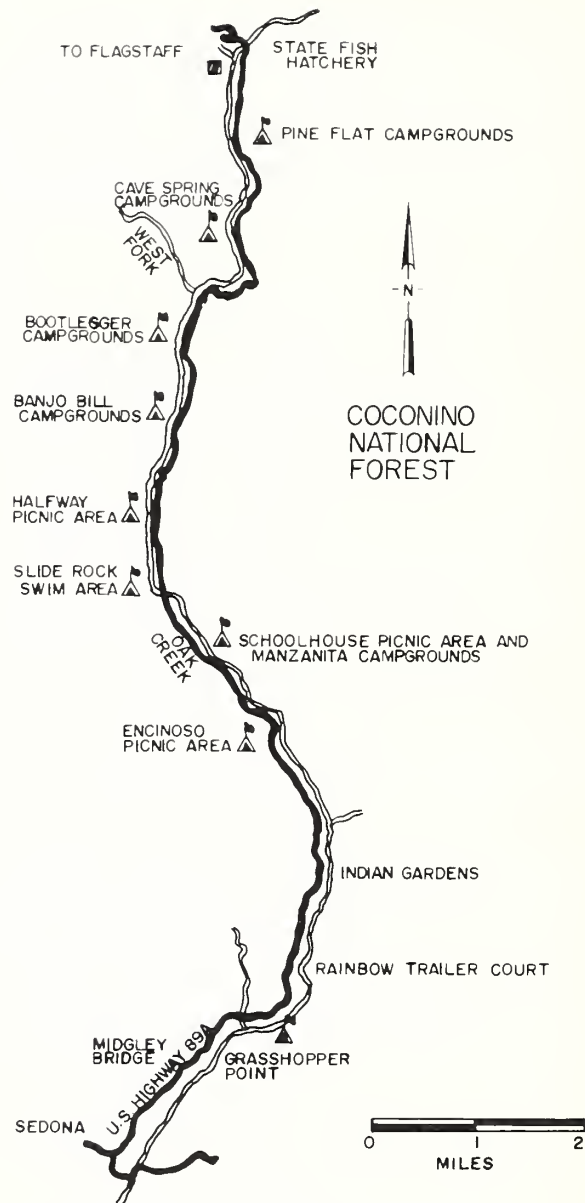


Figure 3.--Oak Creek Canyon.

The studies showed that soils in the canyon are generally deep enough for subsurface wastewater disposal. Percolation rates varied from 4 to 50 minutes per inch and in general, soils that exhibit percolation rates in excess of 30 minutes per inch are suitable for subsurface sewage disposal. At rates below 60 minutes per inch, i.e., when time per inch of water surface subsidence exceeds 60 minutes, the soil is considered unsuitable for subsurface disposal (6) (7). Soil description and percolation test data are shown in Table 6.

Table 6.--Soil description and percolation rates, Owl Creek Canyon

	Soil texture	Soil depth <i>feet</i>	Depth to water table <i>feet</i>	Percolation rate <i>minute/inch</i>
North Canyon Entrance	Sandy loam	4	50	-
Pine Flats Campgrounds	Sand	5	20	-
Cave Springs Campgrounds	Gravel and sand	5	10	4
Banjo Bill Campgrounds	Sand	3	3	7
Slide Rock	Sand	5	Deep	-
Manzanita Campgrounds	Sand	-	-	7
Indian Gardens Trailer Park	Clay/sandy loam	5	Deep	47
Encinoso Picnic Area	Sand	6	-	-
Midgley Bridge	Clay/sandy loam	1.5	-	-
Grasshopper Point	Gravel/clay/sand	4	-	30

Percolation Test Procedures

Percolation test procedures differ, and, as a result, percolation rate information, collected by different individuals at the same location, often varies widely. Recently, within the State of Arizona, efforts have been made by Winneberger and Klock to standardize percolation test procedures (8). The test procedure is as follows: Test holes are made 15 inches in diameter and an inch of coarse sand is placed on the bottom of each hole prior to presoaking. Soils that exhibited clay textures are soaked overnight. Tests are conducted with the apparatus shown in Figure 4. The test consists of filling a hole with water to a depth of exactly 6 inches above the soil bottom. The elapsed time required for the water surface to drop 1 inch is recorded and the procedure is repeated until the recorded time is approximately constant. Results are expressed in minutes per inch of water surface subsidence.

Discussion

Results of percolation tests and soils analyses indicate that soils in Oak Creek Canyon are generally suitable for subsurface sewage disposal systems, except along the banks of the stream. Percolation rates vary from adequate to exceedingly rapid throughout the canyon.

High infiltration rates are not necessarily always desirable. The more rapidly water seeps through the soil, the less opportunity there is for waste assimilation. This is a significant problem when septic tanks and drainage fields are located in close proximity to flowing streams or groundwater.

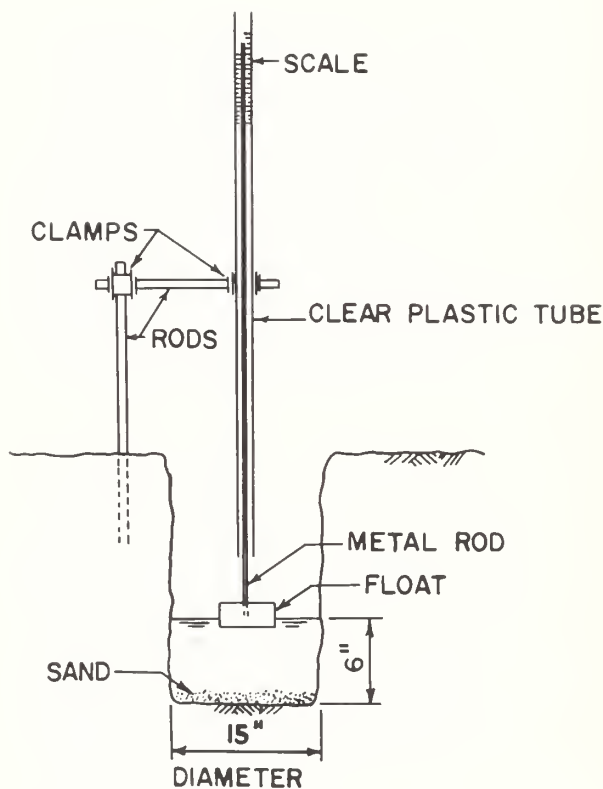


Figure 4.--Soil percolation test apparatus.

Past Wastewater Disposal Practices

The most desirable home and trailer locations are along Oak Creek and sites with a view of the red sandstone formations near Sedona. Unfortunately, many of these sites

are in outcrop areas and are not suitable for subsurface waste disposal systems. In years past, this has led to numerous illicit waste disposal practices, including direct discharge to Oak Creek, using wells for waste disposal and poorly designed septic tank systems. This sort of practice has been eliminated in recent years by County Health Department licensing and inspection.

County Regulations

Sewage disposal within Oak Creek Canyon is under the jurisdiction of the Arizona State Health Department and Coconino County Department of Public Health. The general provisions for the protection of receiving streams in Arizona are set forth in Section 36-1858 of the Arizona Revised Statutes. The general provisions of state law that have significance to this study are outlined in the County regulations (9):

"No sewage or industrial waste shall be permitted to flow into or be placed or deposited into any of the waters or upon or under any of the lands of the county in any manner determined by the department to be detrimental to the quality of the receiving body of water or the use of the receiving lands, or prejudicial to the health, safety or welfare of persons who may be affected by the resulting environmental conditions. No sewage or industrial waste shall be permitted to flow into waters of the county that are used for recreational or domestic purposes

The use of cesspools for waste disposal is prohibited.

Septic tanks will not be permitted under the following conditions: (1) where connection to a public sewage system is determined by the department to be practical, (2) and where soil conditions or topography is such that septic tank systems cannot be expected to function satisfactorily, or where groundwater conditions are such that septic tank systems may cause pollution to the ground water."

The general provisions of the county code also place restriction on construction of septic tank systems for more than one dwelling or commercial unit.

"The use of an individual sewage disposal system on more than one property, dwelling, commercial unit, or other premise is prohibited unless it can be shown to the satisfaction of the health officer that such properties, dwellings, commer-

cial units or premises are constructed, designed and located in such a manner that it is impractical or impossible to construct separate individual sewage disposal systems for them."

Most importantly, for the purpose of this report, the county codes specifically restrict the discharge of sewage from septic tank systems to water courses:

"The effluent from individual sewage disposal systems may not discharge onto the surface of the ground, into any water course, abandoned well, pit, mine, or similar excavation or anywhere where it may pollute, tend to pollute, or create a hazard to any potential or actual water supply or water supply system . . ."

County and State codes are quite specific on design requirements for individual septic tank systems. These requirements encompass size and design features of the various components of the systems, including length and depth of the soil absorption fields. The requirements also pertain to construction materials and most importantly, required minimum distances from wells, water lines, water courses, etc. Of interest to this report is the fact that the minimum distance required by county regulations from a water course is 50 feet and in practice a 100-foot requirement is adhered to. This is a requirement placed upon the septic tank, the distribution box and absorption field piping.

The area required for absorption fields for septic tank systems is based upon percolation rates. Residential absorption area requirements for percolation rates, which varies from 10 to 60 minutes per inch, are 165 to 350 square feet, respectively. The code states that percolation rates slower than 60 minutes per inch will be acceptable for absorption fields or absorption bed installations, only at the discretion of the health authority.

Chemical and Microbial Contamination of Oak Creek

In the traditional sense, Oak Creek is not polluted. Sewage flows are not observed along the banks of the creek. Particulate materials, obnoxious odors, water discoloration, algal blooms, the characteristics of gross pollution, are not observed within Oak Creek Canyon. But there are chemical and biological problems associated with existing wastewater disposal practices in the area.

Pollutants may enter Oak Creek in a variety of ways. Swimmers and people fishing and camping along the stream or its tributaries are potential sources of pollution. Discharge of kitchen and bathroom wastes from campers constitutes a potential source of pollution. Septic tank systems that are improperly designed, or illicit waste disposal systems that do not make use of the soil's capacity to assimilate wastes, are still other sources of pollution. All of these sources are intermittent and thus are difficult to detect by periodic stream sampling and water analysis. Yet considering the extensive use of Oak Creek for swimming, these potential sources of pollution have public health significance.

Individual contamination is controlled within Oak Creek Canyon by restricting overnight campers to prescribed area, and by providing vaulted privies at campgrounds and swimming areas. At the present time, recreational vehicles are prevented from discharging wastes to the stream by Forest Service surveillance and the reluctance of most individuals to pollute the forest environment. Waste disposal facilities for recreational vehicles would further reduce this potential source of pollution, but facilities are not available in the Sedona area.

Contamination by second home developments is suspected along Oak Creek, although sources of apparent direct sewage discharge to Oak Creek have been eliminated in recent years. The reasons for an assumption of periodic contamination are as follows:

1. When most of the older second homes were built, design and installation of septic tank systems was loosely controlled by the county and state.
2. Springs flow near the ground surface through a number of home developments. These developments have septic tank disposal systems.
3. Slime growths are observed along the banks of Oak Creek below homes.

Chemical and Bacteriological Analyses

Chemical and bacteriological examination of Oak Creek water were conducted during the summer of 1973 to determine the level of pollution in the stream and to find sources of stream contamination. The tests consisted of measuring water temperature, monitoring chloride concentrations, and bacteriological analyses for coliform group organisms.

Analyses were conducted routinely during the months of June, July and August, 1973, at

a field laboratory provided by the Forest Service. Several factors were considered in selecting water characteristics for the study. Quality characteristics were required which indicate sewage pollution, are not totally removed in percolation through soil and are relatively easy to test for at a field laboratory. Most sewage characteristics, including organics, nitrogen, phosphorous, detergents, and organic dyes, are nonconservative, taken up by soil, or often difficult to differentiate from background levels after dilution in a surface or ground water.

Approximately 30 mg/l of chlorides are added to water during domestic use, and chlorides are not diminished in passage through the soil. The chloride test was meaningful only when analyzing a suspected sewage discharge, since varying concentrations in spring water and dilution tended to mask the sewage fraction in stream water.

Raw sewage contains about a billion coliform bacteria per 100 ml. These organisms are effectively removed in soil, but when the soil assimilation process is bypassed because of poorly designed or illicit septic tank systems, these organisms can be detected in stream and spring waters, even after manifold dilution.

Sewage contamination of spring water was presumed when microbial counts were an order of magnitude greater than stream water counts. Contamination of a section of Oak Creek was presumed when levels were consistently more than twice average stream background levels.

Results of Bacterial and Chemical Analyses

Analytical results of chemical and biological examination of Oak Creek water are shown in Table 7. The results of membrane filter tests for coliform group organisms indicated that concentrations found in Oak Creek are generally better than limits of acceptability set for bathing waters. Coliform counts in samples taken from Oak Creek were higher adjacent to second homes and trailers in the Indian Garden area. High coliform counts were also observed in samples of bank seepage in this area. Relatively high values observed during one sampling period were caused by storm runoff several days prior to sampling.

Chloride concentration in stream water varied from approximately 1 mg/l at the northern end of the canyon to about 2 mg/l near Sedona. Slightly higher chloride concentrations were generally observed in spring water in the Indian Gardens area. These

Table 7.--Bacteriological and chemical analyses

Sampling Location	Chloride Concentration (mg/l as Cl ⁻)							Coliform Group Organisms per 100 ml.						
	6/26	6/27	Date		7/12	8/1	8/8	6/26	6/27	7/4	Date	7/12	8/1	8/8
			7/4	7/5							7/5			
Fish Hatchery	1.3							0						
Pine Flat Campgrounds	1.2							30						
Cave Spring Campgrounds	1.0	1.2	1.0	1.1	1.1	0.6	1.4	90	90	0	40	40	270	120
Bootlegger Campgrounds	1.5		1.1	1.0	1.3	0.8	1.2	90		0	20	40	260	60
Banjo Hill Campgrounds			0.7	0.8	1.1	0.7	1.3			0	70	80	460	30
Slide Rock	1.5	1.8	0.8	1.0	1.4	1.1	0.7	0	150	100	140	10	480	440
Manzanita Campgrounds	1.4		0.7	1.0	1.3	1.2	0.5	40		0	60	250	440	130
Indian Gardens -- Mainstream		2.0	1.9	1.7	1.5	0.9	1.5	350	90	0	20	80	>1000	450
Indian Gardens -- west bank seepage -- 50' upstream of steel rail bridge		6.6	7.1	25.1	8.8				500	200	0	3600		
Indian Gardens -- west bank seepage -- 100' downstream of steel rail bridge		9.8	7.8	10.0	13.0				100	0	4400			
Indian Gardens -- bank seepage at NE corner of wooden bridge	3.2	2.8	3.1	2.8	3.5	3.3	3.1	10	700	0	100		600	1000
Indian Gardens -- bank seepage at SW corner of wooden bridge				3.0	4.0	3.5	3.2					1300	1300	40
Rainbow Trailer Court		2.2							230					
Grasshopper Point	1.6		2.1	1.9	2.1	2.2	2.1	0		40	0	120	300	160
Route 179 Bridge, South of Sedona				2.0	2.2	2.6	2.2				100	400	100	150

higher chloride values are attributed to naturally occurring salinity, except at two locations where extremely high values suggested the possibility of sewage contamination.

A parallel study of Oak Creek was conducted by the Arizona State Health Department during August, 1973. Water analyses included fecal coliform, dissolved oxygen, and specific ions (Table 8). These data indicate that the stream is relatively unpolluted with bacteria of human or animal origin. Background levels of fecal coliform ranged from 20 to 40 organisms per 100 ml. of sample. High values were observed on a few occasions, but specific sources of contamination were not apparent. Between the headwaters of Oak Creek and Sedona, water quality remained unchanged. Dissolved oxygen remained at saturation levels, pH was neutral, and the specific ions and nutrients, listed in Table 8, remained constant.

Discussion of Stream Pollution

Determining if subsurface sewage disposal systems are polluting a stream is, at times, quite difficult. The discharge of pollutants, by second homes, into a stream, if it occurs

at all, is sporadic. It varies with the time of year, quantity of sewage discharged, groundwater levels, and whether or not springs flush through an area. Many times little or no pollution emanates from systems that were neither designed nor installed correctly. At other times, bacterial and other contaminants of sewage origin may contaminate the stream. It is this periodic discharge of contaminants that makes testing difficult. In addition, the traditional tests for pollution were designed for drinking water supplies and require repetitive testing to establish levels of contamination. A single analysis of stream water or bank seepage usually indicates very little. Conclusions drawn from the bacteriological data shown on Table 7 are based upon the sum total of the eighty examinations, each of which was duplicated. These data show higher bacterial levels adjacent to second home developments than are apparent at other locations along Oak Creek. These data also indicate that springs under developed areas are being contaminated periodically. The single State Health Department bacterial analysis of Oak Creek near Indian Gardens did not yield increased bacterial counts. However, the State Health Department's analyses did yield high bacterial counts further downstream at the Rainbow Trailer Park.

Table 8.--Water quality data - Oak Creek (Source of data: Arizona State Department of Health)*

	Bridge on Hwy 179--Sedona	Grasshopper Point	Rainbow Trailer Park--Bridge	Below Slide Rock	Above Slide Rock	West Fork at Confluence with Oak Creek	Oak Creek above West Fork	Below Pumphouse Wash
Dissolved Oxygen, mg/l	8.5	12	10	-	-	11	10	11
pH (field)	6.5	7	6.9	7	7	6.9	7	6.8
pH (lab)	8.4	8.6	8.4	-	-	8.2	8.3	8.5
Conductance (field)	194	282	272	310	300	298	265	249
Conductance (lab)	270	260	263	-	-	270	270	240
Flow, cfs	-	15	15	15	-	0.5	8	5
Stream Temperature, °C	21	23	21	23	20	24	23	18
Hardness, mg/l as CaCO ₃	153	152	155	-	-	179	164	137
Calcium	42	40	42	-	-	39	48	36
Magnesium	11	30	12	-	-	19	11	8
Sodium	5	7	5	-	-	2	4	3
Iron	<.05	-	<.05	-	-	<.1	<.05	<.05
Total Nitrogen	1	-	1	-	-	-	-	< 1
Bicarbonates as CaCO ₃	155	156	156	-	-	167	162	138
Carbonates as CaCO ₃	6	8	8	-	-	4	8	9
Chloride	4	3	3.4	-	-	3	3	2.5
Nitrate	< 1	< 1	< 1	-	-	< 1	< 1	< 1
Sulfate	6	6	7	-	-	6	8	6
Phosphate	0.1	0.4	0.3	-	-	0.3	0.4	0.4
Total Dissolved Solids	199	155	208	-	-	192	196	180
Turbidity	0.9	0.4	0.4	-	-	1	0.5	0.3
Fecal Coliform (geom. mean)	33	5	35	9.3	22	47	-	23

*Samples were collected between August 8 and August 22, 1973. Values shown are averages of 2 to 6 analyses.

Protecting Surface and Ground Waters From Biological and Chemical Contaminants

Sewage contains a variety of chemical and biological materials in both particulate and dissolved form. Septic tanks are essentially solids-handling devices, not treatment processes. Contaminants are either held and treated in soil or they pass to surface and ground waters.

Organic materials are partially or completely oxidized in soil; bacteria and viruses

are effectively removed by filtration and absorption; metals, e.g., aluminum, copper, iron, manganese, phosphorus, zinc form insoluble compounds and precipitate out in soil; other elements with high solubilities, e.g., chlorides are not reduced by percolation through soil. Calcium, magnesium, potassium and boron may be partially removed, depending on soil pH and the solubility of their various compounds. Organic nitrogen is oxidized in soil, but nitrogen concentrations are usually only partially diminished.

Nitrogen, phosphorous, carbonaceous materials, bacteria and viruses are the principal contaminants in domestic sewage and are of particular importance in stream and ground water degradation. The removal of nitrogen, phosphorous, organic compounds and micro-organisms in the soil is dependent upon the characteristics of the organisms and nutrient material being removed, soil properties, chemical and biological processes that occur in the soil, the rate and manner of flow through the soil, surface vegetation, climate and a variety of other variables.

The reason the fate of substances in soil is evaluated is to predict its assimilative capacity, or, conversely, to define minimum distance requirements between soil disposal systems and surface or ground water resources.

The size of soil particles, the nature of a soil mass, and the rate of flow through soil are particularly important in preventing stream and ground water contamination. Soils and rock formations which permit rapid flow through fissures and crevices or underground channels can obviously carry waste materials considerable distances with little contaminant removal or treatment. Underground springs such as those encountered along Oak Creek can carry septic tank effluents rapidly to surface streams. Rapid transport through a soil mass diminishes the effective time available for waste assimilation.

Oxidation of organic materials in soil can vary from minimal amounts to complete oxidation. For well designed septic tank systems in which adequate distances are maintained from surface and ground waters, organic materials normally do not contaminate water supplies. Oxidation processes in the soil are also enhanced by the typical intermittent use of recreational homes. Periodic dosing and recovery periods tend to increase the efficiency of the soil waste treatment process.

Organic nitrogen in sewage is utilized by organisms for energy and oxidized sequentially to ammonia, nitrites, and finally, nitrates. With sufficient detention time in the soil the nitrification process proceeds to the terminal oxidation state, and nitrogen exists as nitrates. If, subsequently, within the soil, decomposition of organic matter produces anaerobic conditions, nitrates are reduced to nitrogen gas. Anaerobic conditions are generally not found in soil; however, experience has shown that denitrification does occur in soil, and, in fact, total nitrogen removal has been achieved in tests (Santee, California, 1500 ft. of percolation). Winneberger suggests that small pockets within a soil mass, e.g., at a decomposing root, can be devoid of

oxygen, thus creating the anaerobic conditions needed for denitrification (10).

In Oak Creek Canyon, the relatively short distances between septic tank drainage fields and the creek, springs that feed the creek or ground water, afford little opportunity for denitrification. But, at the present level of development along Oak Creek, nitrogen entering surface and ground waters will have little influence on stream eutrophication.

Phosphorus is effectively removed from wastewater as it percolates through the soil. Phosphate is absorbed by the soil, and, in conjunction with calcium, aluminum, and iron, forms compounds with low solubilities which precipitate from solution.

Research in recent years had indicated that bacteria are effectively removed from wastewater as it percolates through the soil. Bacteria are filtered from solution in the same manner as particulate and other colloidal materials. The distance L in feet, required for the removal of coliform bacteria from a septic tank effluent, can be estimated from the following equation (11):

$$L = 107 (d)(v)$$

where d is the effective soil grain size in cm (10% by weight is finer than this size), and v is the rate of water movement through the soil in feet per day. Soils in Oak Creek Canyon are classified as sand to sandy loam. The effective grain size is less than .01 cm. If the minimum distance between a septic tank system and ground water, or Oak Creek, is assumed to be 50 feet, then the maximum permissible velocity in accordance with the preceding equation is approximately 50 ft/day. This estimate is several orders of magnitude greater than normal groundwater flow velocities. However, if the groundwater table is near the ground surface or septic tank, effluents are carried by subsurface springs, effective filtration of bacteria cannot be assumed.

Based on the above consideration, groundwater contamination within the canyon, if it occurs at all, is restricted to the immediate vicinity of a waste disposal system. This is also true of illicit disposal systems reported within the canyon that discharge to shallow wells. These conditions do not result in widespread pollution but certainly constitute localized health hazards.

Viruses range in size between .01 and .5 microns, are electrically charged and easily absorbed by soil. Winneberger reports a study in which large quantities of Polio Type 3 vaccine were injected into percolation beds

(12). Water samples collected from a test well 200 ft. from the injection point did not contain viruses. Flow velocity was 100 ft per day. Winneberger states the following:

"Viruses will be removed from percolating waters after 4 inches of travel through a clay soil or about 1 foot of travel through a sand soil."

Based upon the above statement, viral contamination of the surface and ground waters of Oak Creek Canyon appears to be a fairly remote possibilities except when subsurface springs intercept leaching fields. Obviously this condition constitutes a direct discharge to a surface supply and not to a soil assimilation system.

Alternative Sewage Disposal Methods for Oak Creek Canyon

Waste disposal systems in recreational areas should above all else protect the public health and the natural forest environment. The most economical waste disposal methods that provide adequate health and environmental protection should, of course, be chosen. Waste disposal method selection should be based upon present and possible future land use, population density, soil conditions and the reuse potential of domestic sewage. Water is not abundant in Arizona, and the reuse potential of wastewaters in an additional consideration in selecting disposal systems.

Various types of development are possible within Oak Creek Canyon during the next decade. There is a strong likelihood of continued developmental patterns with full development of private land and the Forest Service continuing to maintain and improve campsite and picnic areas. Alternatively, increasing public pressure to utilize the canyon for recreational purposes could result in the exclusion of private development from the canyon proper. The Forest Service could then either develop the canyon extensively for camping by constructing a series of small campgrounds or campgrounds could be eliminated entirely from the canyon. In the latter alternative the canyon would be used exclusively for daytime recreation, and overnight camping would be restricted to one or a number of large campgrounds located north of the canyon.

The Forest Service reported that vaulted privies in day-use picnic areas are pumped an average of once per year at a cost of about \$50 each. This is by far the most economical means of waste disposal for day use recreational facilities. Vaulted privies do not pollute the

immediate environment and can be placed near recreational activity. This is an advantage when a water supply is not readily available and sites are near the stream where soil is generally shallow. A criticism of privies is associated with the problems of pumped solids disposal. However, given the relatively small quantity of waste expected from day-use recreational areas solids, disposal in well managed sanitary landfills should offer little difficulty. Pit privies are aesthetically objectionable to a populace accustomed to modern plumbing. Low water-using privies or conventional bathroom facilities in conjunction with septic tank systems are also feasible for large sites.

People staying overnight in national forest campgrounds generally prefer water-using bathroom facilities, but conventional facilities, are feasible only at a large campground with Forest Service personnel located at the site. A modern campground located north of the canyon, if developed, could utilize septic tank systems for sewage disposal. While effluent from a secondary treatment plant discharged to Oak Creek would pollute the stream, subsurface discharge through septic tank systems could enhance plant growth at a campsite.

Additional small campgrounds could be constructed within Oak Creek Canyon, but from an administrative standpoint, including enforcement of regulations against environmental pollution, this type of development leaves much to be desired.

The vaulted privy is an efficient method of waste disposal if solids accumulation is not excessive, as in day-use recreational areas. At overnight campgrounds, the privies are used more extensively, and tend to accumulate an assortment of refuse. Septic tank systems are feasible only with conventional water-using bathroom facilities which are not practical at numerous small campsites.

There are two basic methods for disposing of sewage from trailer developments and second homes in Oak Creek Canyon; using the soil mantle for waste assimilation, and transporting wastewater through a sewerage system, out of the canyon. Properly designed and installed septic tank systems do not pollute surface or groundwater, they are relatively inexpensive wastewater is available for plant growth. However, not all potential building sites are large enough or have soil of sufficient depth to accommodate leaching fields. The only rationale for providing a sewerage system in Oak Creek Canyon is to foster extensive private home developments. Such a system would concentrate sewage and transfer the disposal problem downstream.

SUMMARY AND CONCLUSION

Summary

The disposal of wastes from vacation-oriented communities that border National Forest lands is a significant environment problem. Sewage discharged to water courses with or without conventional treatment can diminish water quality and restrict the use of water resources and contiguous forest areas.

The waste disposal problem is twofold in the southwestern United States. Wastewater that is not treated adequately or disposed of in an innocuous manner is esthetically objectionable and a potential health hazard. But, wastewaters and their nutrient constituents are valuable resources in water short regions and can be utilized for plant growth both within recreational communities and in the surrounding national forest.

Two field studies were undertaken in northern Arizona to determine the impact of second homes and related recreational development on surface and ground water. The initial study was conducted at an established community of second homes that collects wastewaters in a sewerage system and treats waste materials in a conventional extended aeration sewage treatment plant. Secondary effluent from the plant is used to water a golf course that overlies the community groundwater supply source.

A second study was conducted in a national forest area that has been developed by the Forest Service for public camping and that also contains private home and trailer park developments. Septic tanks and soil treatment are used for waste disposal in this area.

The initial study was conducted at Pinewood, Arizona, a community of 540 homes (1972). The community will ultimately consist of 3,250 homes and trailers, and population density at full development is expected to reach 9 persons per acre within the residential areas. Ten percent of the present total population are year-round residents. The remaining population are in residence primarily on weekends between May and November. Average residence time during 1972 was about 90 days per year.

Water use varies from an average of 6 gallons per capita per day during the winter months to 44 gallons per capita per day during the high water use month of August. These per capita use estimates are based upon 2.5 persons per household and the total homeownership population.

Sewage flow estimates are as follows:

	Gallons per Capita per day	Percent of Maximum Monthly Values
Average Daily Flow (12-month basis)	7	27%
Average Daily Flow (December thru April)	4	14%
Maximum Monthly Flow (August)	26	100%
Maximum Day Flow	33	126%
Peak Hour Flow	43	162%

Daily, monthly and seasonal sewage flow variations are caused primarily by variations in the resident population.

Chemical and bacterial analyses were conducted on samples of sewage, sewage treatment plant effluent, surface water and groundwater. These analyses showed:

- a) chemical and bacterial contaminant concentrations in Pinewood sewage are similar to values reported for residential communities. Average values obtained from analyses conducted at Arizona State University were as follows:

Sewage Characteristic	Concentration
Coliform Group Organisms, MPN per 100 ml	1.6×10^9
Biochemical Oxygen Demand mg/l of 5 day BOD	196
Kjeldahl Nitrogen (Organic Nitrogen and Ammonia) mg/l as N	33.6
Nitrates mg/l as N	0
Phosphorus mg/l as P	10
Chlorides mg/l as Cl	34

- b) the sewage treatment plant at Pinewood normally produces an effluent low in carbonaceous materials, but package treatment plants of the type in use at Pinewood are easily upset, especially when resident population and hence, sewage flow varies widely. Phosphorus, nitrogen, and chloride

concentrations were not significantly diminished in the sewage treatment process.

- c) groundwater analyses at Pinewood indicated no infiltration of the treated sewage effluent used to water the golf course.
- d) during the period of investigation, surface water was present only during and following rainfall. Treated sewage effluent was confined to irrigation holding ponds.

Adoption of septic-tank waste disposal systems for a community requires a combination of adequate plot size to accommodate drainage fields, and soil permeabilities that permit sufficient percolation rates. Only within the area occupied by and adjacent to the golf course at Pinewood, are these conditions satisfied. Where subsurface sewage disposal systems are feasible, this method of wastewater disposal offers at present, the best protection against degradation of the forest environment. The groundwater contamination potential of properly designed systems for low density second home developments is negligible.

A solution to the wastewater disposal problem created by second home developments lies in water reuse, and when feasible, the adoption of subsurface disposal systems. Wastewater and its nutrient constituents are a valuable resource that can be utilized for plant growth through either surface irrigation or subsurface discharge.

The emphasis of the second study was sewage contamination of surface water in Oak Creek Canyon, resulting from subsurface sewage disposal. Soils analyses, percolation tests and chemical and bacterial analyses of Oak Creek water were conducted during the summer of 1973.

Periodic pollution of Oak Creek stems from recreational activity; swimming, camping, fishing and second home use. The present level of second home development and campground activity has not resulted in levels of organic, nutrient, bacterial or viral contamination that impair the quality of Oak Creek or its potential recreational uses. Little information is available on sewage disposal systems for the older residences and trailer parks in the canyon. Springs traverse many of the home sites, suggesting the possibility of sewage discharge to surface waters.

During the months of June, July and August 1973, tests for Coliform bacteria and

chlorides were conducted on water samples taken at various locations along Oak Creek. Results of these analyses indicated that bacterial concentrations found in Oak Creek are generally below acceptable levels prescribed for bathing waters, but counts are higher adjacent to trailer park developments.

Percolation through soil is an effective method of removing many potential pollutants from domestic sewage. With sufficient residence time in the soil, organic material can be totally oxidized and bacteria and viruses effectively removed in relatively short distances. Metals, e.g., aluminum, copper, iron, manganese, phosphorus and zinc form insoluble compounds in soil and precipitate out. Other elements may be partially removed (calcium, magnesium, potassium and boron) or not removed at all (chlorides and sodium). Organic nitrogen is oxidized in soil to nitrates but long travel distances through soil are required to deplete nitrogen concentrations.

Waste disposal systems for three alternative forms of development in Oak Creek canyon were investigated: (1) restricting the entire canyon to daytime public use, (2) extensive overnight camping facilities throughout the canyon, and (3) an expansion of the present mixed type of development, i.e., second homes, campsites and picnic areas. Conclusions pertaining to available sewage disposal methods for each pattern of development are illustrated in Table 9.

Additional alternatives at picnic areas and campsites are low-volume and chemical recirculating toilets. The low volume flush toilet can work with as little as one quart of water. Chemical recirculating units recirculate liquid waste that has been treated to reduce odors. These and similar types of facilities can reduce odor problems encountered at campsites, but they do require increased pumpage and maintenance. However, well constructed and maintained vaulted privies need not be offensive nor will they pollute the forest environment. In addition, they cost far less to install and maintain than mechanical devices or a sewerage and sewage treatment system.

Conclusions

Wherever possible, sewage disposal systems should be adopted for campgrounds or encouraged at second home developments that utilize the assimilative capacity of the environment.

Contrary to current trends in wastewater management and regulation, it is the modern

Table 9.--Sewage disposal methods

<u>Disposal Method</u>	<u>Restricting Canyon to Daytime Use</u>	<u>Extensive Campsite Development</u>	<u>Second Homes Campsites & Picnic Areas</u>
Vaulted Privies	preferred method economical, least pollution potential requires well maintained sanitary land fill for disposal	acceptable method water using facilities preferred	acceptable at campsites and picnic areas
Septic-Tank Systems	applicable if water provided on site at large campgrounds	recommended only at large campsites	preferred method for second homes
Low Volume Flush Toilets and Chemical Recirculating Toilets	acceptable	acceptable	acceptable
Individual Sewage Treatment Units	Additional research and development is needed in this area. Effluent from units may still constitute sources of surface or groundwater contamination.		
Sewers & Secondary Treatment	not recommended		

methods of wastewater conveyance and treatment (sewers and secondary treatment) that present the most serious threat to a forest environment, rather than the age-old individual disposal methods (soil disposal, privies). If a septic tank or privy fails, the problem is significant but localized. If a sewage treatment plant serving a second home development fails or does an incomplete job of containment reduction, the detrimental effect on the forest environment is of much greater magnitude. The key to waste disposal for second homes is not the adoption of septic tanks per se, but rather utilization of the soil waste assimilative capacity. It is areas such as Oak Creek Canyon that assimilative capacity is extensive and can support relatively concentrated development or campsite use. At Pinewood, individual soil disposal systems are not feasible at home sites. Lot sizes are too small and the soil mantle too shallow. However, a community septic tank system could have been built in the golf course in lieu of the existing sewage treatment plant. A septic tank and leaching field disposal system in the golf course area would have provided essentially the same treatment and disposal of wastewater at the same location, for considerably less capital and operating cost. The treatment plant does serve to provide recycled water for the golf course.

Forest Service activities in preventing pollution of National Forests include establishing and enforcing recreational land use regulations on forest land, liaison with State and local health authorities, and consideration of the impact of development in land purchase and exchange. Some specific suggestions to further these activities include:

a. Enforcing overnight camping regulations in extensively used recreational areas, and strict enforcement of regulations against the discharge of wastes from camper-type vehicles.

b. Acquainting Forest Service personnel with camper waste disposal practices in their area and encouraging the development of disposal facilities in conjunction with municipal solid or sewage disposal works. Disposal facilities should not be provided in a recreational area such as Oak Creek Canyon where operating a waste disposal facility is undesirable.

c. An awareness of County and State health and pollution abatement laws and regulations governing the installation and operation of waste disposal systems. Observation of waste disposal practices in second home developments, and a close working arrangement with County Sanitarians, is important.

Biological and chemical analyses of surface and ground waters is expensive and requires a great deal of replication before results are conclusive. To prevent surface and ground water pollution, sanitary surveys should be relied upon as well as strict adherence to and enforcement of health, pollution abatement and waste system design and installation standards.

Land acquisition and exchange is an area of activity in which the Forest Service can exert a direct influence on stream and ground water contamination by second home developments. Impact studies are suggested prior to land exchange studies that consider modes of development and waste disposal practices on released and acquired land. The environmental impact of wastes discharged by communities established on released land, or, conversely, the beneficial effects of eliminating development on acquired land should be considered.

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